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Navigation Environment In A Medical Institution: An Eye-Tracking Examine

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Abstract**:** ***Navigation and wayfinding are well-known issues that people face in their life every day. In many situations, and especially in the case of medical facilities, it is vital that users find the desired destination quickly and successfully. This is not only about comfort, but also about life and health safety. In this regard, the development of an effective navigation system becomes an extremely important mission for health care institutions. Therefore, the eye-tracking technology, which makes it feasible to look at the problem through visitor's eyes, appears to be a pertinent tool for an objective assessment of the existing navigation, as well as finding ways to optimize it. This article considers present approaches to the analysis of navigation systems dealing with a large number of clients and describes our visual navigation study conducted in a health center. The first part of our study included the current navigation environment evaluation and the decision-making points detection, serving as a starting point for the implementation of a new, user-oriented navigation in the medical center. In the second part of the study the effectiveness of the applied system was confirmed. The results obtained show that navigation environment improvement can significantly reduce users' time to reach the goal, as well as length of their route. Thus, we managed to apply the eye-tracking method to the improve user experience in a medical establishment.***

Keywords : eye-tracking, navigation, user experience, wayfinding.

I. INTRODUCTION

Navigation in the surrounding space is an integral part of modern human life. Both a designer and a user would confirm that a properly designed navigation system is a factor which determines the comfort of using any environment. What is more interesting, this fact is true not only for the external urban environment but also for the internal space of private and public organizations. An intuitive and simple navigation system is the cornerstone of a good user experience (UX) [1]. Furthermore, the ease or the difficulty of reaching the necessary location often affects users' opinion on the institution, as well as their impression of it. Therefore, the creation of a user-friendly navigation system becomes a primary goal for all organizations, and especially for those dealing with a significant customer flow.

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In order for the navigation system to be effective, it is necessary to make sure that the navigation elements pass through the user's perception threshold and overlap the background neural noise, which includes the fatigue effects, the level of users' attention fluctuation, as well as their

motivation to perform a task associated with the signal detection [2]. Thus, as a result of successful perception, navigation elements should reach the user's consciousness. At the same time brain research conclusively proves that human mind is strongly influenced by subconscious neural activity [3]. Such knowledge about the brain is actively used in neuromarketing, a currently popular science branch employing methods both of neurophysiology and marketing. The issues of this new scientific field are considered by such researchers as Paul Glimcher [4], Douglas L. Fugate [5], Christophe Morin [6] and Nick Lee et al. [7]. Providing objective assessment of visual perception based on unconscious physiological indicators, neuromarketing techniques are of particular interest to researchers in a variety of areas, including designers and marketers. The information obtained with the help of this method helps to gain a great insight into the consumers' decision-making process.

Eye-tracking technology is considered to be one of the main neuromarketing tools. It gives researchers an opportunity to track and record eye movements, such as pupil movement and dilation, and thus captures user's visual attention. The data collected with an eye-tracker is presented for the further analysis as a video track which reflects such user's behavior characteristics as pathway, travel speed and eye movement patterns. Eye-tracking has broad application in marketing research, specifically in UX studies, since it allows one to determine which design elements were noticed by the consumer and which were ignored [8].

The eye-tracking method is also of a particular interest for the designers who seek to achieve a deeper understanding of how users visually interact with products or technologies. Given the presence of eye-tracking systems that can measure users' gaze patterns on computer screens, designers and researchers can use eye-tracking to answer a wide range of questions about users' visual behavior, cognition, as well as visual attention strategies [9].

As already mentioned earlier, the main advantage of eye-tracking is the objectivity of the collected data, which are based on the fixation of the main physiological processes underlying the motivation behind the certain forms of consumer behavior. Thus, eye-tracking provides researchers with precious visual information about user's behavior when using a product [10].

Moreover, the employment of this technology enables developers to exercise control over each stage of product creation, making it possible to assess whether its design meets the convenience criteria from the users' point of view. This also applies to navigation systems, which can serve as such product. However, despite being such a relevant topic, the use of eye-tracking in the development and evaluation of navigation is not studied enough and only begins to attract researchers' attention.

The subject under consideration was investigated by such authors as Brugger A. et al. [11], Kiefer P. et al. [12], Müller S. et al. [13], Franchak J. et al. [14], showing that eye-tracking is an extremely useful tool for assessing the effectiveness of existing navigation elements, as well as for proving the need for their placement. Instead of using assumptions based on generalized models, eye-tracking technology provides researchers with the exact data representing where the visual attention of specific users is directed. Using eye-tracking, designers can objectively identify what part of the space the user is actually looking at, and, accordingly, make better use of the five key visual elements known to attract individual's attention: faces, intensity, edges, blue-yellow contrast and red-green contrast [15].

In order to explore the UX of a space in terms of navigation, we conducted an experimental study on visual navigation of visitors in the Medical Center No. 29, Novosibirsk. The study included 2 parts: the first one was carried out before the introduction of the new navigation system while the second part took place after its implementation. The purpose of the first part of our study was to analyze the existing navigation system of the medical center for its further improvement; the purpose of the second part was to verify and confirm the effectiveness of the implemented navigation elements. In both parts of the study we evaluated UX using eye-tracking technology.

II. MATERIALS AND METHODS

The study was conducted in the Medical Center No. 29 (both in children's and adult departments).

A. Participants

Twelve healthy adults participated in the first part of the study (3 males, 9 females, mean age: 40 years). The second part of the study also involved twelve participants (3 male, 9 females, mean age: 36 years) but all of them were re-selected in order to avoid learning effects. All the participants were current or potential visitors to the medical center. This number of participants is sufficient to obtain reliable results if analyzing the scan paths, as well as making general conclusions using heat maps.

B. Equipment

Participants' eye movements as they moved around the medical center were recorded using wearable SMI iViewETG™ tracking glasses (Sampling rate: 30 Hz) connected to the SMI Recording Unit™.

C. Procedure

The registration process started from the entrance to the medical center. During both parts of the study participants were given two (in rare cases, three) specific tasks in which they were to find the necessary office by its number or by the name of the doctor. The tasks were different for all the participants, though some offices could coincide. Participants were not allowed to ask anyone for additional information, they were to find the offices without any hints. Once a participant completed one of the tasks, they immediately moved on to the next. The time to complete the task was not restricted. After completing all the tasks the participant had to find the way out of the medical center.

The tasks of the second part of the study almost completely repeated the tasks of the first one, although the location of two offices changed due to the transformations occurred in the medical center. However, these changes have not become any significant, so, in our opinion, their impact on the results obtained can be neglected.

In addition to eye movements, participants' pathways were also tracked for further study and identification of decision-making points, the areas of space in which user makes a choice about where to move next, and in which, respectively, navigation elements should be placed. The pathways were also needed for the subsequent comparative analysis of the participants' locomotion in the clinic during the first and the second parts of the study.

It should be noted that during the registration process in the first part of the study one of the participants dropped the recording device, thereby the recording was interrupted and the participant was unable to perform the second task.

D. Experimental tasks

The list of tasks given to the participants during the first part of the study is presented below in Table I.

Table I: The 1st part tasks

Participant	Tasks		
	Task 1	*Task 2*	*Task 3*
Part. 1	Pediatrician Burnysheva T. V. (of. 259)	Ultrasound room 327	–
Part. 2	Massage room 345	Physical therapy room 423	–
Part. 3	Otolaryngologist's office 233	X-ray room 116	–
Part. 4	Ophthalmologist T. N. Lutsenko (of. 349)	Blood test room 142	–
Part. 5	Treatment room 347	WC	–
Part. 6	Ultrasound room 327	–	–
Part. 7	Therapist Adamovich N. O. (of. 306)	Vaccination room 207	–
Part. 8	Women's consultation registry	Obstetrician-gynecologist's office 313	–
Part. 9	Traumatologist's office 205	Office for sick leaves 141	–
Part. 10	Head of the therapeutic department, of. 226-227	Head of the medical center, of. 433	–

Participant	Tasks		
	Task 1	*Task 2*	*Task 3*
Part. 11	General blood test, room 109	Biochemical blood test, room 214	WC
Part. 12	Therapist Adamovich N. O. (of. 306)	Vaccination room 207	Physiotherapist's office 410

The list of tasks given to the participants during the second part of the study is presented below in Table II.

Table II: The 2nd part tasks

Participant	Tasks		
	Task 1	*Task 2*	*Task 3*
Part. 1	Pediatrician Burnysheva T. V. (of. 259)	Ultrasound room 327	–
Part. 2	Massage room 345	Physical therapy room 423	–
Part. 3	Otolaryngologist's office 349	X-ray room 116	–
Part. 4	Ophthalmologist T. N. Lutsenko (of. 335)	Blood test room 142	–
Part. 5	Treatment room 251	WC	–
Part. 6	Ultrasound room 327	–	–
Part. 7	Therapist Adamovich N. O. (of. 306)	Vaccination room 207	–
Part. 8	Women's consultation registry	Obstetrician-gynecologist's office 313	–
Part. 9	Traumatologist's office 205	Office for sick leaves 141	–
Part. 10	Head of the therapeutic department, of. 226-227	Head of the medical center, of. 433	–
Part. 11	General blood test, room 109	Biochemical blood test, room 214	WC
Part. 12	Therapist Adamovich N. O. (of. 306)	Vaccination room 207	Physiotherapist's office 410

As it can be seen from the tables, the only difference between the tasks of the first and the second part is Task 1 for the Participants 3, 4 and 5. It is worth repeating that the impact of these changes on the results can be considered insignificant since these offices are located in the same department and differ no more than one floor.

E. Data analysis

The collected data were subsequently analyzed in the program SMI BeGaze™, version 3.6.52. Concerning eye movements analysis tools, scan paths, i.e. the sequence of fixation points, were used as the main tool for assessing the visitors' attention. We have chosen scan paths because they give us the key to identifying problem areas in the medical center, as well as finding the decision points. Besides, it is this tool that could provide us the most complete understanding of the participants' locomotion nature in relation to the navigation environment of the center.

F. Analysis for the 1st part of the study

The eye movements analysis done during the first part of the study consisted of two blocks. First, we examined the participants' locomotion while they were navigating through the medical center, taking into account all stops, changes of direction and difficulties occurred. This allowed us to draw pathways for each participant. Then, basing on these data, we proceeded directly to the eye movements analysis, i.e. the study of the participants' gaze patterns. In order to do this, we have divided the entire time taken by the participant to complete all the tasks into intervals of about 30 seconds. After that, we have counted the number of fixations made by a participant at each interval and established their gaze direction. This information about the participant's eye movements was displayed on the their pathway as a cone. The direction of the cone reflects the direction of the participant's gaze while its color intensity represents the number of fixations at the time interval. A darker shade corresponds to a bigger number of fixations, a lighter shade is equal to few fixations. The gradient coloring of each cone consists of two or three parts depending on how often the number of fixations in the area has changed over time. Thus, a section of the same shade displays a time interval corresponding to 10 or 15 seconds approximately. Such work was carried out for each participant and for all floors of the medical center.

It should be noted that during the first part of the study we have decided not to analyze eye movements in relation to navigation elements as the navigation system presented at that time in the medical center was poor, and hence carrying out such an analysis seemed to us inexpedient.

G. Analysis for the 2nd part of the study

As long as the navigation environment in the medical center has changed a lot since the introduction of the new navigation system, and now our task was not to identify problem areas or find the decision points but to check the effectiveness of the implemented navigation system, the means of analyzing the data collected have also changed during the second part of our study. Our analysis was designed to demonstrate how much easier it has become for participants to navigate in the medical center and find the right offices. So, in this case we analyzed the following three parameters:

1. Task execution time (and, especially, its change in comparison with the first part);
2. Pathways (also in comparison with the first part);
3. Eye movements in relation to the navigation elements.

The results of our analysis for both parts of the study are presented in the next section.

III. RESULTS

A. Results of the 1st part

A visual representation of the eye movements analysis, as well as the participants' pathways during the first part of the study for the first floor of the medical center is presented below in Figure 1.

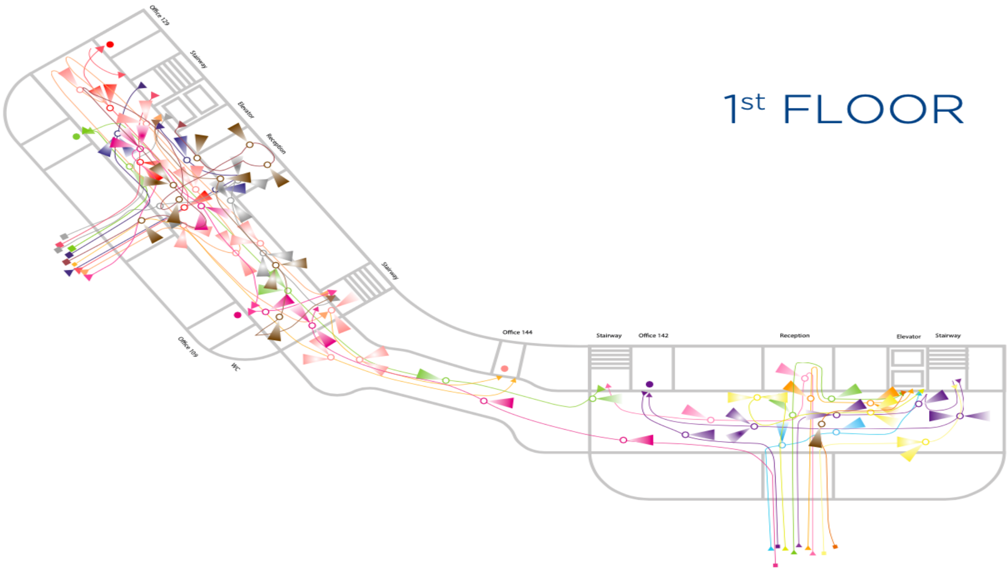

Fig. 1

The same representations for 2-4 floors of the medical center are given in the Appendix.

Based on the results of the first part of our study, we have identified the primary, the secondary and the tertiary decision-making points. These are presented below in Table III.

Table III: The decision-making points

	Primary decision-making points	*Secondary decision-making points*	*Tertiary decision-making points*
1	Entrance to the medical center	The area near the main stairway	The area near the second stairway
2	The area near the reception	The area near the elevator	The center of the passageway
3	The area near the entrance to the elevator		The end of the medical center corridor
4	The area near the entrance to the passageway		

Figure 2 shows the location of all decision-making points for the 1st floor of the medical center.

On the other floors of the medical center the decision-making points appear to be the same except for the entrance to the center and the space near the reception.

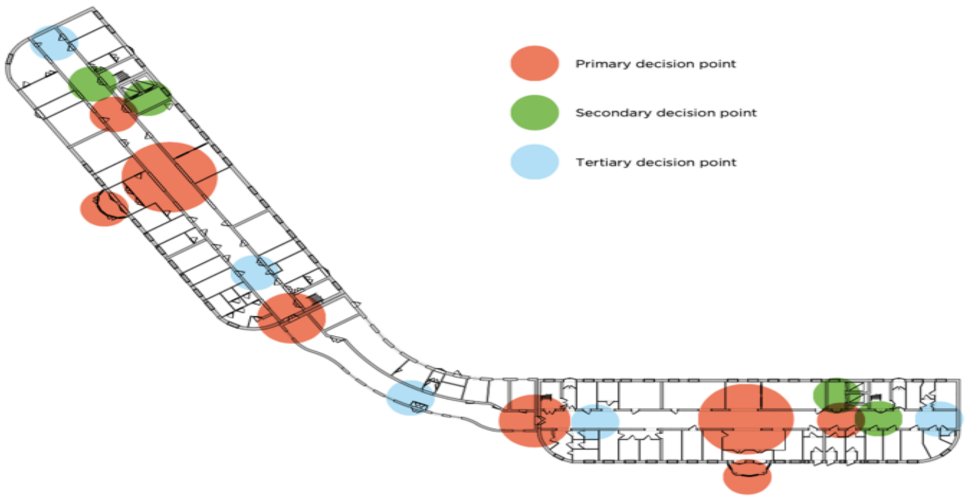

Fig. 2

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Thus, our analysis during the first part of the study accurately and representatively reflected the data on the participants' eye movements and at the same time on their locomotion in the medical center. This allowed us to determine with great confidence the decision-making points at which the new navigation elements were subsequently placed. Following these findings a new navigation system was introduced in medical center. Its effectiveness will be further analyzed during the second part of the study.

B. Results of the 2nd part

As mentioned earlier, during the second part of the study we analyzed the effectiveness of the implemented navigation system in relation to three parameters:

1. Task execution time (and its change in comparison with the first part);
2. Pathways (also in comparison with the first stage);
3. Eye movements in relation to the navigation elements.

Let us proceed with the first of them, i.e. with the task execution time.

C. Task execution time

We examined the task execution time from two sides. First, we analyzed the time to complete each task by all participants, as well as the total execution time (which is the sum of the time to complete all the tasks and the time to find the exit from the medical center). In addition to the absolute time, we also calculated the relative change in the task execution time (in %) during the second part compared to the first. These results are presented in Table IV.

In this table and all subsequent ones red font corresponds to a slower task execution, green font – to a faster one. In other words, if during one part a participant completed the task slower, than during the other, the time for this part is highlighted in red; if faster, then in green.

The table shows that after the introduction of the new navigation the task execution time has reduced almost for all of the tasks. This analysis helps us to visualize the overall changes but it does not take into account the fact that the tasks differed in complexity.

Therefore, secondly, we grouped the tasks by their complexity and calculated the average total execution time by groups.

When grouping tasks by complexity we considered such factors as:

- The location of the offices which a participant was to find on the same floor/on the nearby floors vs. the location of the offices with a difference > 1 floor;
- The location of the offices in the same vs. different departments.

Thus, we have assigned the tasks for the participants 4, 5, 7, 8, 11 to simple tasks, namely:

Simple tasks			
Participant	***Task 1***	***Task 2***	***Task 3***
Participant 4	Ophthalmologist T. N. Lutsenko (of. 349/335)	Blood test room 142	–
Participant 5	Treatment room 251 (347)	WC	–
Participant 7	Therapist Adamovich N. O. (of. 306)	Vaccination room 207	–
Participant 8	Women's consultation registry	Obstetrician-gynecologist's office 313	–

Simple tasks			
Participant	***Task 1***	***Task 2***	***Task 3***
Participant 11	General blood test, room 109	Biochemical blood test, room 214	WC

Tasks given to the participants 1, 9 and 12 were attributed to average on complexity tasks (the task for the participant 6 could also fit into this category, however since the recording for this participant was interrupted during the 1st part of the study and he not was able fulfill the second task we decided not to attribute this task in any of the categories):

Average tasks			
Participant	***Task 1***	***Task 2***	***Task 3***
Participant 1	Pediatrician Burnysheva T. V. (of. 259)	Blood test room 142	–
Participant 9	Traumatologist's office 205	WC	–
Participant 12	Therapist Adamovich N. O. (of. 306)	Vaccination room 207	Physiotherapist's office 410

Finally, the tasks for the participants 2, 3 and 10 were considered as difficult.

Difficult tasks			
Participant	***Task 1***	***Task 2***	***Task 3***
Participant 2	Massage room 345	Physical therapy room 423	–
Participant 3	Otolaryngologist's office 349 (233)	X-ray room 116	–
Participant 10	Head of the therapeutic department, of. 226-227	Head of the medical center, of. 433	–

For each of the groups we calculated the average total task execution time, as well as its relative change during the second part of the study compared to the first part. These data are presented below in Table V.

Table V: Average total execution time of different tasks and its relative change during the 1st and 2nd parts

Task Complexity	*1st part*	*2nd part*
Simple tasks	4 min 52 sec	3 min 50 sec (- 21 %)
Average tasks	7 min 20 sec	4 min 53 sec (- 33 %)
Difficult tasks	13 min 33 sec	7 min 15 sec (- 46 %)

It follows from this table that the more difficult the tasks were, the stronger is the positive impact of the new navigation system on the speed of the task execution. This is quite natural because the more complex is the task, the more often people refer to the navigation elements while performing it. And we see that properly placed navigation elements can significantly facilitate the task of finding a remote office reducing the execution time for complex tasks almost twice.

D. Pathways

In addition to the task execution time, during the second part of the study we also analyzed the participants' pathways while navigating in the medical center. This was done, first of all, in order to compare the pathways to those of the first part. Moreover, this method also allowed us to evidently demonstrate how the nature of participants' locomotion in the medical center has changed since the introduction of the new navigation system.

The participants' pathways during the second part of the study for the first floor of the medical center are shown below in Figure 3.

The pathways for 2-4 floors of the medical center are presented in the Appendix.

Finally, the last analysis parameter during the second part of the study is considered, which is the participants' eye movements in relation to navigation elements.

E. Eye movements in relation to navigation elements

When analyzing eye movements our goal was to identify all the participants' visual actions in relation to the navigation elements which led to a successful task execution, as well as to assess the impact of these actions on the final result. In other words, we needed to describe the following chain: "setting a task -> capturing navigation elements -> achieving the goal", further evaluating the second element effectiveness. However, before proceeding directly to the study of the participants' visual interaction with the medical center navigation environment, it is necessary to introduce a brief classification of navigation elements in order to ensure a correct understanding of their functions and explain the further elements differentiation in our analysis.

Table IV: Task execution time and its relative change during the 1st and 2nd parts of the study

	Task 1		Task 2		Task 3		Total time	
	1st part	**2nd part**	**1st part**	**2nd part**	**1st part**	**2nd part**	**1st part**	**2nd part**
Part. 1	1 min 54 sec	1 min 05 sec (- 43 %)	2 min 21 sec	3 min 19 sec (+ 41 %)	–	–	5 min 23 sec	5 min 50 sec (+ 8 %)
Part. 2	2 min 34 sec	2 min 23 sec (- 7 %)	3 min 56 sec	2 min 12 sec (- 44 %)	–	–	8 min 30 sec	6 min 20 sec (- 25 %)
Part. 3	3 min 19 sec	2 min 09 sec (- 35 %)	2 min 40 sec	3 min 37 sec (+ 36 %)	–	–	6 min 46 sec	6 min 44 sec (- 0,5 %)
Part. 4	2 min 34 sec	1 min 33 sec (- 40 %)	2 min 44 sec	58 sec (- 68 %)	–	–	4 min 55 sec	3 min 10 sec (- 36 %)
Part. 5	3 min 46 sec	1 min 10 sec (- 67 %)	1 min 12 sec	1 min 09 sec (- 4 %)	–	–	5 min 41 sec	4 min 43 sec (- 17 %)
Part. 6	3 min 15 sec	3 min 50 sec (+ 18 %)	–	2 min 07 sec	–	–		6 min 25 sec
Part. 7	2 min 21 sec	1 min 40 sec (- 29 %)	1 min 15 sec	1 min 05 sec (- 13 %)	–	–	4 min 58 sec	4 min 30 sec (- 9 %)
Part. 8	59 sec	1 min 05 sec (+ 10 %)	1 min 26 sec	1 min 24 sec (- 2 %)	–	–	3 min 44 sec	3 min 49 sec (+ 2 %)
Part. 9	2 min 16 sec	1 min 27 sec (- 36 %)	5 min 3 sec	1 min 04 sec (- 79 %)	–	–	8 min 45 sec	3 min 15 sec (- 63 %)
Part. 10	2 min 57 sec	1 min 11 sec (- 60 %)	19 min 13 sec	6 min 20 sec (- 67 %)	–	–	25 min 23 sec	8 min 41 sec (- 66 %)
Part. 11	47 sec	21 sec (- 55 %)	1 min 27 sec	49 sec (- 44 %)	45 sec	36 sec (- 20 %)	5 min 02 sec	2 min 58 sec (- 41 %)
Part. 12	2 min 45 sec	1 min 38 sec (- 41 %)	1 min 01 sec	47 sec (- 23 %)	1 min 49 sec	1 min 32 sec (- 16 %)	7 min 51 sec	5 min 33 sec (- 29 %)

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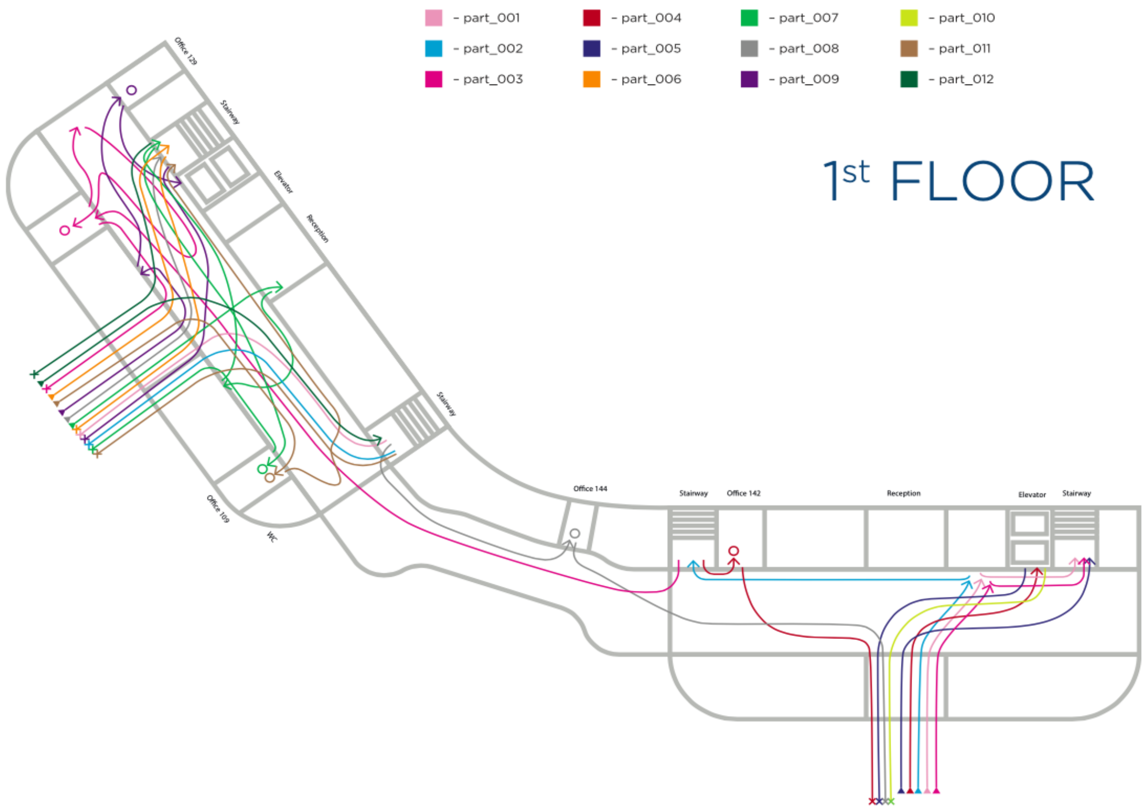

Fig. 3

So, below we describe the types of navigation elements we have selected with the necessary explanations.

Types of navigation elements:

1. Information boards (are located on the 1st floor in both departments);
2. Hanging signs (are located on all floors of both departments, as well as in the passageways indicating the department/passageway/exit);
3. Wall signs:

- In the department corridors:
  - Schematic maps (are located on each floor in both departments representing a schematic image of the medical center and indicating the floors, as well as main functional areas);
  - Corridor direction signs (small signs located on each floor in both departments in the amount of 6-8 containing the basic information about the nearest offices);
- In the passageways/near the passageways:
  - Schematic maps (are located in the center of the passageways and look similar to the corridor schematic maps);
  - Transition signs (small signs located at the entrances and exits to/from the passageways in both departments containing the information about the offices in the passageway);
- In the stairways:
  - Stairway schematic maps (are located on each floor of a stairway in both departments representing a schematic image of the current department and indicating the floors, as well as main functional areas);
- In the elevator/near the elevator:
  - Elevator schematic maps (are located in the elevator lobbies on each floor in both departments and look similar to the stairway schematic maps);
  - Elevator signs (small signs located in the elevator lobbies on each floor in both departments containing the basic information about the nearest offices on the current floor).

It is obvious that when performing different tasks, people refer to different navigation elements, so in certain tasks some of them play the crucial role while others go by the wayside. We kept in mind all these factors when interpreting data on participants' eye movements in relation to the new navigation elements in order to correctly assess how the implementation of a new navigation system contributed to a faster and more successful task performance.

The results of the participants' eye movements analysis during the second part of the study are presented below in Tables VI-VIII.

The abbreviations used in the tables are deciphered as follows:

t. t. f – time to find (the time until the participant finds the object of interest);

d. t – dwell time (the time during which the participant 's gaze dwell in the area of interest);

e. c – entry count (the number of the participant's gaze entries in the area of interest).

Table VI: The results of the eye movements analysis for the 1st task

	Task 1																				
	Information board		Signs																		
			In the department corridors						In/near the passageways						In the stairways		In/near the elevator				Goal
			Schematic maps		Corridor direction signs		Hanging signs		Schematic maps		Transition signs		Hanging signs		Stairway schematic maps		Elevator schematic maps		Elevator signs		
	t. t. f	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	t. t. f
Part.1	15 sec	9 sec	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	41 sec
Part.2	13 sec	28 sec	–	–	6	8 sec	–	–	–	–	2	5 sec	–	–	2	11 sec	–	–	–	–	9 sec
Part.3	15 sec	13 sec	–	–	2	2 sec	1	1 sec	–	–	–	–	–	–	2	4 sec	–	–	–	–	8 sec
Part.4	14 sec	2 sec	–	–	1	1 sec	1	1 sec	–	–	–	–	–	–	–	–	1	2 sec	1	1 sec	7 sec
Part.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2 sec	–	–	–	–	20 sec
Part.6	18 sec	3 sec	3	20 sec	3	19 sec	1	4 sec	–	–	–	–	1	2 sec	1	6 sec	–	–	–	–	4 sec
Part.7	–	–	–	–	–	–	1	1 sec	–	–	–	–	–	–	1	5 sec	–	–	–	–	7 sec
Part.8	–	–	1	20 sec	3	4 sec	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10 sec
Part.9	–	–	1	3 sec	1	1 sec	3	3 sec	–	–	–	–	–	–	–	–	–	–	–	–	10 sec
Part.10	–	–	–	–	4	4 sec	–	–	–	–	–	–	–	–	1	5 sec	–	–	–	–	22 sec
Part.11	–	–	–	–	2	3 sec	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6 sec
Part.12	–	–	–	–	4	12 sec	2	4 sec	–	–	1	3 sec	–	–	2	5 sec	–	–	–	–	15 sec

Table VII: The results of the eye movements analysis for the 2nd task

	Task 2																		
	Signs																		Goal
	In the department corridors						In/near the passageways						In the stairways		In/near the elevator				
	Schematic maps		Corridor direction signs		Hanging signs		Schematic maps		Transition signs		Hanging signs		Stairway schematic maps		Elevator schematic maps		Elevator signs		
	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	t. t. f
Part.1	3	12 sec	5	5 sec	–	–	1	2 sec	–	–	–	–	–	–	–	–	–	–	13 sec
Part.2	1	3 sec	1	1 sec	1	1 sec	1	2 sec	2	3 sec	–	–	2	5 sec	–	–	–	–	11 sec
Part.3	1	1 sec	2	7 sec	4	4 sec	–	–	3	8 sec	2	2 sec	2	9 sec	–	–	–	–	12 sec
Part.4	–	–	–	–	–	–	–	–	1	1 sec	–	–	2	3 sec	–	–	–	–	11 sec
Part.5	–	–	1	1 sec	2	4 sec	–	–	–	–	–	–	–	–	–	–	–	–	12 sec
Part.6	1	5 sec	1	2 sec	1	1 sec	1	2 sec	–	–	–	–	–	–	–	–	–	–	14 sec
Part.7	–	–	1	1 sec	2	2 sec	–	–	–	–	–	–	–	–	–	–	–	–	11 sec
Part.8	–	–	2	2 sec	1	1 sec	–	–	–	–	–	–	–	–	1	2 sec	1	1 sec	1 sec
Part.9	–	–	–	–	–	–	–	–	1	1 sec	1	1 sec	1	1 sec	–	–	–	–	10 sec
Part.10	2	12 sec	9	12 sec	2	2 sec	–	–	3	8 sec	1	1 sec	1	3 sec	1	3 c	–	–	37 sec
Part.11	–	–	1	2 sec	1	2 sec	–	–	–	–	–	–	1	4 sec	–	–	–	–	1 sec
Part.12	–	–	2	6 sec	–	–	–	–	–	–	–	–	2	4 sec	–	–	–	–	18 sec

Table VIII: The results of the eye movements analysis for the 3rd task

	Task 3																		
	Signs																		Goal
	In the department corridors						In/near the passageways						In the stairways		In/near the elevator				
	Schematic maps		Corridor direction signs		Hanging signs		Schematic maps		Transition signs		Hanging signs		Stairway schematic maps		Elevator schematic maps		Elevator signs		
	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t	e. c	d. t.	t. t. f
Part.11	–	–	2	4 sec	2	2 sec	–	–	–	–	–	–	–	–	–	–	–	–	20 sec

Part.12	–	–	**2**	**2 sec**	–	–	–	–	–	–	–	–	**2**	**5 sec**	–	–	–	–	**26 sec**

Along with that, each of the tasks had its own "relevant" navigation elements, i.e. the elements, the participant's reference to which guaranteed the successful task execution. The relevant navigation elements for each task are marked in the tables above with light yellow color.

If a participant found the goal faster during the 2nd part of the study than during the 1st one, the time to find the goal in tables 6-8 was marked with green color, if slower then with red color.

Thus, it follows from these tables that in most cases the participants capturing of the relevant navigation elements contributed to a faster and more successful goal finding, while skipping relevant elements led to a less successful task execution.

Nevertheless, in some cases even having detected relevant navigation elements the participants were unable to find the goal rapidly. This situation occurred to Participant 3 during Task 2 and to Participant 6 during Task 1. In these cases, obviously, the participant's cognitive abilities have influenced the task performance, which cannot be completely neglected.

However, this fact does not change the overall picture. It has been proved that correctly placed and, consequently, noticed by participants navigation elements greatly contribute to a successful task execution.

IV. DISCUSSION

The results obtained by the end of the study confirm that the navigation system implemented in the medical center is appropriate, coping with its tasks successfully.

After the introduction of the new navigation system the time for participants to complete tasks was significantly reduced. More precisely, the average total execution time for simple tasks has decreased by 21 % during the 2nd part of the study compared to the 1st part; for average tasks, the execution time has decreased by 33%. Finally, the most significant change occurred for difficult tasks: here the average total execution time has decreased by 46% compared to the 1st part.

In addition to the task execution time, the picture regarding the participants' pathways has changed substantially. Before the introduction of a new navigation participants experienced major difficulties while navigating in the medical center and it was clearly reflected in their pathways. Therefore, the pathways of the 1st part of the study are extremely complex and confusing. In contrary, the pathways of the 2nd part demonstrate how dramatically changed the nature of the participants' locomotion in the medical center after the improvement of its navigation environment. Here we can see that individuals no longer moved spontaneously in search of the right office. As long as participants' locomotion has become much less chaotic and much more purposeful, their pathways have also grew much clearer.

The observed changes in the task execution time, as well as in the participants' pathways are largely explained by the nature of their interaction with navigation elements. The results of the eye movements analysis in relation to navigation elements confirmed that finding the elements relevant for a particular task predisposed a faster and more successful achievement of the goal by a participant compared to the 1st part of the study. This fact, in its turn, confirms that the navigation system introduced in the medical center after the 1st part of our study was placed correctly, functioning effectively and handling its objectives.

V. CONCLUSION

Once again we note that all cases of slower task performance by specific participants can be explained solely by their cognitive abilities. It is evident from the eye movements analysis that these participants captured all relevant to the task navigation elements. However, apparently these elements were misinterpreted by the participants due to their individual characteristics.

In total, the results of our research show that a properly implemented and effectively functioning navigation system makes it much easier for visitors to interact with an unknown environment ensuring that they achieve their goals as quickly and easily as possible.

APPENDIX

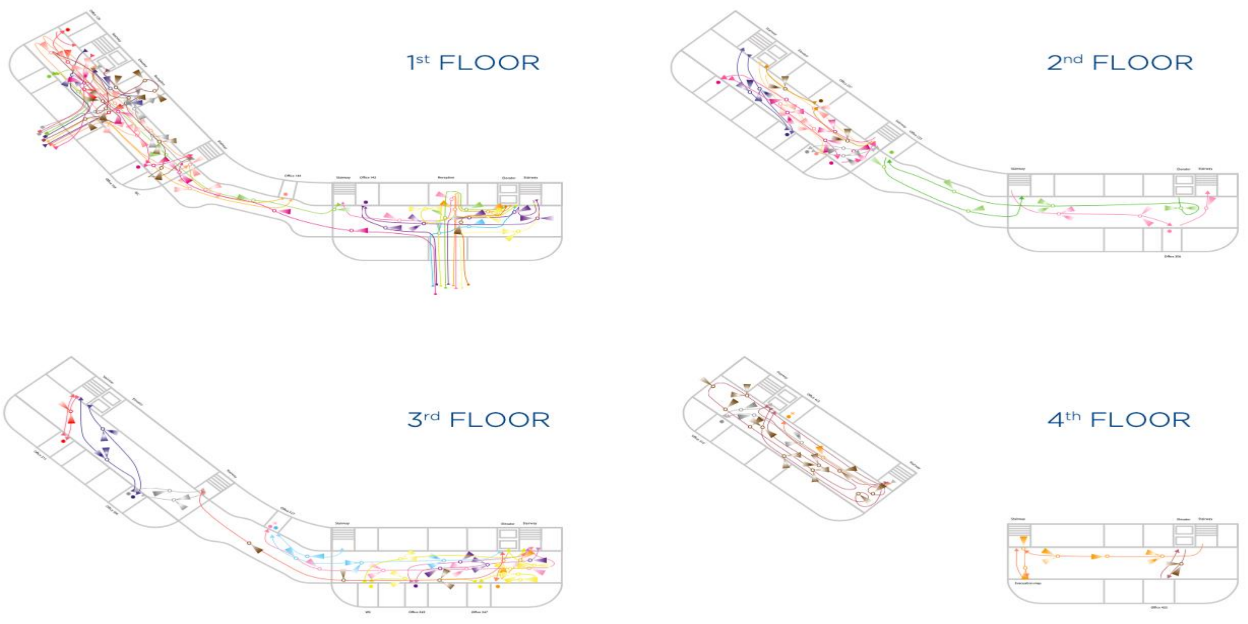

Fig. 4. Participants' pathways and eye movements analysis for the 1st part of the study

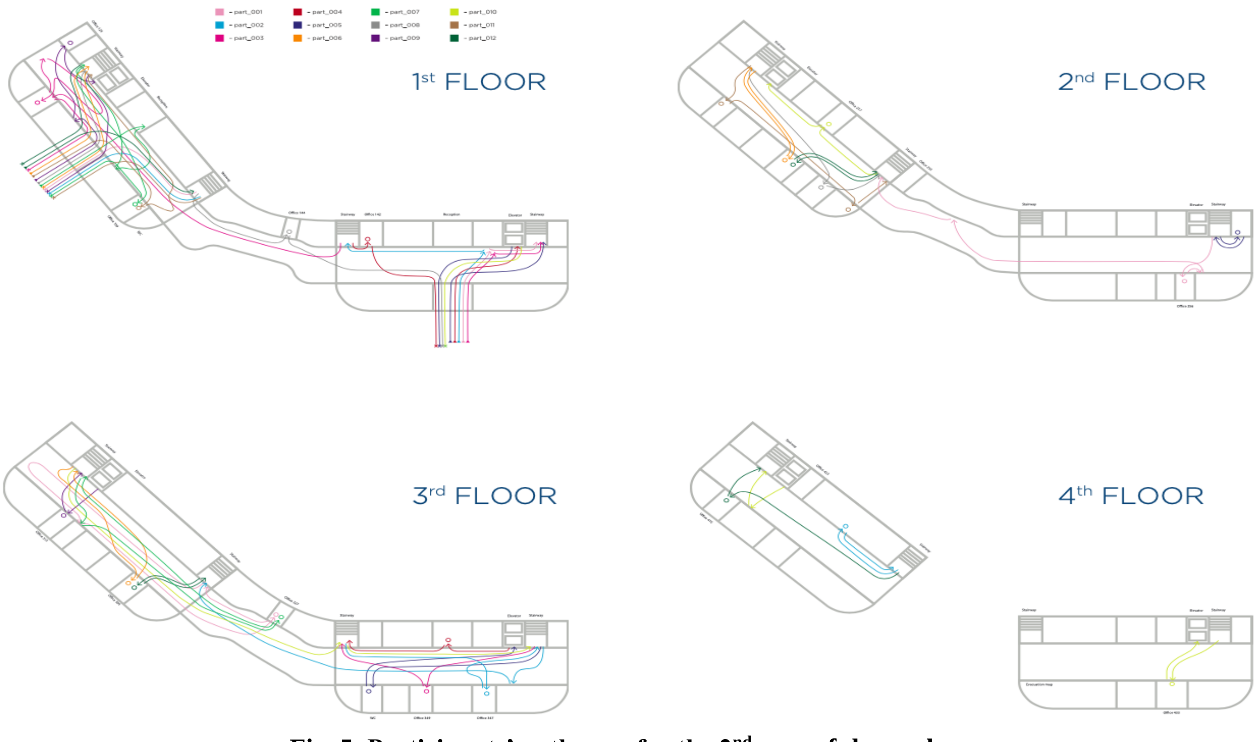

Fig. 5. Participants' pathways for the 2nd part of the study

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REFERENCES

1. A. Shall, Eye Tracking Insights into Effective Navigation Design. In: Marcus A. (eds) Design, User Experience, and Usability. Theories, Methods, and Tools for Designing the User Experience. DUXU 2014. Lecture Notes in Computer Science, vol 8517. Springer, Cham (2014).
2. H. R. Schiffman, 2001. Sensation and perception: an integrated approach, 5th ed. New York: John Wiley & Sons, In.
3. A. Traindl, 2007. Neuromarketing: die innovative Visualisierung von Emotionen. Trauner.
4. P. W. Glimcher, 2009. Neuroeconomics: Decision-making and the brain. London: Elsevier.
5. D. L. Fugate, 2007. Neuromarketing: A layman's look at neuroscience and its potential application to marketing practice. Journal of Consumer Marketing, 24(7), 385–394.
6. C. Morin, 2011. Neuromarketing: The New Science of Consumer Behavior. Society, 48(2), 131–135.
7. N. Lee, L. Broderick & L. Chamberlain (2006), What is 'neuromarketing'? A discussion and agenda for future research. International Journal of Psychophysiology, 63, 200–204.
8. K. Pernice. J. Nielsen, 2009. How to conduct eyetracking studies. Freemont, USA Available: https://www.nngroup.com/reports/how-to-conduct-eyetracking-studies/

9. E. Medina, E. Cuddihy, E. Goldberg, J. Ramey, Uses of eye tracking technology in design. Proc Hum Factors Ergon Soc Annu Meet 52(19). 2008. P. 78-86.
10. A. T. Duchowski, 2007. Eye tracking methodology: Theory and Practice, 2nd ed. Springer.
11. A. Brügger, K. F. Richter & S. I. Fabrikant (2019), How does navigation system behavior influence human behavior?. Cognitive research: principles and implications, 4(1), 5.
12. P. Kiefer, I. Giannopoulos, M. Raubal, A. Duchowski (2017), Eye tracking for spatial research: Cognition, computation, challenges. Spat Cogn Comput 17(1–2):1–19.
13. S.C. Mueller, C.P.T. Jackson, R.W . Skelton, Sex differences in a virtual water maze: An eye tracking and pupillometry study. Behav Brain Res 2008; 193:209–15.
14. J.M. Franchak, K.E. Adolph, Head-mounted eye-tracking of natural locomotion in children and adults. Vision Research. in press.
15. M. Tang, C. Auffrey, Advanced digital tools for Updating Overcrowded Rail Stations: Using Eye Tracking, Virtual Reality, and Crowd Simulation // Springer. 2018. P. 33-41.

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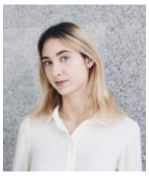

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